

## RINGKASAN

Kemasan pintar berbasis film kitosan yang dilapisi ekstrak kubis merah telah dikembangkan sebagai sensor kesegaran daging ayam yang responsif terhadap perubahan pH selama penyimpanan. Film ini memanfaatkan antosianin sebagai indikator alami perubahan warna, dan kitosan sebagai matriks polimer yang biodegradabel. Matriks kitosan dimodifikasi dengan penambahan grafena oksida (GO) dan agen penaut silang glutaraldehida (GA) untuk meningkatkan sifat mekanik, aktivitas antibakteri, dan stabilitas film.

Penelitian ini dilaksanakan dalam tiga tahapan, yaitu: (1) sintesis GO menggunakan metode Hummers, karakterisasi GO dengan *X-ray Diffraction* (XRD) dan *Fourier Transform Infra Red* (FTIR), dan ekstraksi kubis merah melalui metode maserasi; (2) sintesis film kitosan terlapis kubis merah dengan variasi agen penaut silang GA (CG0,0; CG0,5; CG1,0; CG1,5) dan sintesis film dengan penambahan GO (CGO 0%; CGO 0,25%; CGO 0,5%; CGO 0,75%); dan (3) karakterisasi dan pengujian film, meliputi analisis gugus fungsi (FTIR), morfologi permukaan (FE-SEM), stabilitas termal (TGA-DSC), kuat tarik, hidrofilitas (sudut kontak), transparansi visual, aktivitas antibakteri, dan aplikasi sebagai sensor kesegaran daging ayam.

Hasil penelitian menunjukkan bahwa sintesis GO berhasil ditandai dengan munculnya gugus fungsi khas GO (O-H, C=O, C=C, dan C-O) pada spektra FTIR dan puncak difraksi  $10,52^\circ$  pada hasil XRD. Film kitosan/GA terlapis ekstrak kubis merah (CG) menunjukkan nilai kuat tarik, sudut kontak, dan aktivitas antibakteri optimum pada variasi CG0,5, serta mengalami penurunan massa sebesar 54-63% pada uji biodegradabilitas. Film kitosan dengan penambahan GO (CGO) menunjukkan nilai kuat tarik dan sudut kontak tertinggi pada CGO0,75%, aktivitas antibakteri tertinggi pada CGO0,25%, serta penurunan massa sebesar 40-60% pada uji biodegradabilitas. Film kitosan dengan variasi GA dan GO yang dilapisi ekstrak kubis merah berhasil menunjukkan perubahan warna dari ungu menjadi hijau dalam 48 jam penyimpanan daging ayam, sehingga berpotensi diaplikasikan sebagai sensor kesegaran dalam kemasan daging ayam segar.

## SUMMARY

*A smart packaging film based on chitosan and coated with red cabbage extract was developed as a freshness sensor for chicken meat, responsive to pH changes during storage. The film employs anthocyanins as natural color-change indicators and chitosan as a biodegradable polymer matrix. The chitosan matrix was modified by the addition of graphene oxide (GO) and glutaraldehyde (GA) cross-linking agent to improve the mechanical properties, antibacterial activity, and film stability.*

*This study was conducted in three stages: (1) synthesis of GO using the Hummers method, characterization of GO by X-ray Diffraction (XRD) and Fourier Transform Infra Red (FTIR), and extraction of red cabbage using maceration; (2) preparation of chitosan film coated with red cabbage extract using various of GA cross-linking agent (CG0.0, CG0.5, CG1.0, CG1.5) and GO (CGO 0%, CGO 0.25%, CGO 0.5%, CGO 0.75%); and (3) film characterization and performance testing, including chemical structure analysis (FTIR), surface morphology (FE-SEM), thermal stability (TGA–DSC), mechanical strength, hydrophilicity (contact angle), visual transparency, antibacterial activity, and application as a chicken meat freshness sensor.*

*The results showed successful GO synthesis, indicated by the presence of characteristic functional groups (O-H, C=O, C=C, and C-O) in the FTIR spectra and a diffraction peak of 10.52° in the XRD results. The chitosan/GA film coated with red cabbage extract (CG) exhibited optimal tensile strength, contact angle, and antibacterial activity at the CG0.5 formulation, along with 54-63% weight loss in the biodegradability test. The GO-modified chitosan films (CGO) showed the highest tensile strength and contact angle at CGO 0.75%, and the highest antibacterial activity at CGO 0.25%, with 40-60% weight loss. The films exhibited a visible color change from purple to green within 48 hours of chicken meat storage, indicating their potential application as visual freshness sensors in fresh meat packaging.*